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Resistance in Cultivated Sunflower Germplasm to the Red Sunflower Seed Weevil (Coleoptera: Curculionidae) in the Northern Great Plains

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ABSTRACT: A 5 yr field study evaluated 49 sunflower, *Helianthus annuus* L., accessions, and 5 interspecific crosses for resistance to infestation by naturally occurring populations of the red sunflower seed weevil, *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae). Germplasm with potential sources of resistance to attack was identified. The accession PI 162453 averaged only 8% damaged seed per head in 3 yr of testing and PI 431545 averaged 8% damaged seed per head in 4 yr of trials. The accessions PI 431542 and PI 650375, which were tested for five years, averaged 5% and 10% damaged seed per head, respectively over the study. PI 431542 averaged less than 6% in all but one year of testing. Additional accessions that appeared promising in two consecutive years of trials included PI 195573, PI 219649, PI 250085, and PI 432516. Hybrid 894 consistently had high seed damage from *S. fulvus* feeding. Results revealed potential for developing resistant genotypes for decreasing seed feeding injury by the red sunflower seed weevil. Research is in progress to introgress resistance genes from the identified lines into cultivated sunflower through conventional breeding facilitated by the use of marker-assisted selection.

KEY WORDS: *Smicronyx fulvus*, host plant resistance, sunflower, *Helianthus*

The red sunflower seed weevil, *Smicronyx fulvus* LeConte, is a major economic pest of sunflower, *Helianthus annuus* L. in the northern production region of North Dakota, South Dakota, and Minnesota (Oseto and Braness, 1979; Charlet *et al.*, 1997). In the central Plains, the red sunflower seed weevil is present and a potential pest of cultivated sunflower in Colorado and Kansas because of increasing populations of weevils (Aslam and Wilde, 1991; Charlet and Glogoza, 2004). A native insect pest, *S. fulvus* emerges from the soil in early summer and moves to sunflower heads (capitula) feeding on the involucral bracts. At anthesis, the adults feed on pollen and females deposit eggs in the developing sunflower seeds (Oseto and Braness, 1980; Brewer, 1991; Rana and Charlet, 1997). Red sunflower seed weevil larvae feed in the developing sunflower achenes (kernels) destroying a portion of the kernel and reducing oil content. When mature, larvae exit the seeds in late summer and overwinter in the soil, emerging as adults the following summer. There is only one generation per year (Oseto and Braness, 1979; Peng and Brewer, 1995).

Pest management strategies that have been investigated to prevent yield losses from *S. fulvus* include insecticides (Gednalske and Walgenbach, 1984; Oseto and Burr, 1990), trap cropping (Brewer and Schmidt, 1995), tillage (Gednalske and

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Walgenbach, 1982), and planting date (Oseto *et al.*, 1987; Charlet, 2002). There also is a limited amount of information on the natural enemies of the red sunflower seed weevil (Pinkham and Oseto, 1987; Charlet and Seiler, 1994; Charlet, 2002). Some research has also included resistance in cultivated and native species (Brewer and Charlet, 1995; Charlet and Seiler, 1994; Gao and Brewer, 1998). The objective of this study was to evaluate sunflower germplasm for potential resistance to red sunflower seed weevil. Studies were initiated in South Dakota in 2003 and sunflower germplasm was exposed to naturally occurring weevil infestations to evaluate differences in seed damage caused by this insect pest.

Materials and Methods

During the 2004 to 2008 growing seasons 49 sunflower accessions and 5 interspecific crosses were evaluated for resistance to infestation by naturally occurring populations of the red sunflower seed weevil. Each year, USDA sunflower hybrid '894' also was included as a check in trials. A preliminary trial in 2003 had shown means of over 40% *S. fulvus* damaged seed per head among some of the breeding lines and interspecific crosses evaluated. The sunflower accessions were obtained from the USDA Plant Introduction Station, in Ames, Iowa. Interspecific crosses were provided by one of the authors (G.J.S.). Trials were conducted at the South Dakota State University Central Crops and Soils Research Station, in Highmore, South Dakota. 17 to 25 entries were evaluated annually in single row plots 8 m long, with rows 76 cm apart, and plants spaced 30.5 cm apart within rows; $\sim$ 54,000 plants/ha. Entries with relatively low levels of seed damage per head were retested in subsequent years and some susceptible lines also were selected for continued evaluation. Plots were planted between 16 May and 20 June each year in a randomized complete block design with four replicates, except from 2005 to 2008 when only three replicates were used. Plots received a preplant application of fertilizer and herbicide, but no other chemical treatments were used for insect control during the season.

The degree of infestation was measured by calculating the percentage of damaged seed with evidence of *S. fulvus* larval feeding per head. Five heads per row (total of 15–20 per treatment) were removed after plants had senesced. Sunflower heads were harvested from late September to October and sent to Fargo, North Dakota. Heads were dried, threshed, and the seed cleaned prior to evaluation. The GLM analysis of variance option (SAS, 2008) was used to compare percentage of seed damaged per head among the different treatments for each study year. Percentages were transformed to the square root of the arcsine prior to analysis. Means were separated using the Fisher protected least significant difference (LSD) test (Carmer and Walker, 1985) at $P < 0.05$.

Results

There were significant differences in percentage of damaged seed per head by larvae of the red sunflower seed weevil among the germplasm tested from 2004 to 2008, with over 40% damaged seed per head in the most susceptible lines in three of the five years (HIR 828-3 and PI 650558) and over 32% in the other two years of testing (PI 650558 and Hybrid 894) (Table 1).

The determination of damage in the 2004 trial showed that high levels of red sunflower seed weevil infestation occurred with a range of 6 to 49% damaged seed per head among the germplasm tested (Table 1). Those showing damage levels of 13% or less included the three accessions PI 431513, PI 497939, PI 650375, and PI 431542 and were significantly lower than nine of the 17 accessions evaluated this year. PI 650375 in a preliminary trial in 2003 had shown only 13% damaged seed per head. Hybrid 894 averaged 24% damaged seed per head which was similar to results from the preliminary trial in 2003. The interspecific cross, HIR 828-3, selected as a susceptible check had the greatest damage in the 2004 trial at 49% damaged seed. Two other interspecific crosses, STR 1622-1 and STR 1622-2, which were retested because of relatively low injury in 2003, sustained damage higher than the plot average of 26% damaged seed in the 2004 trials, at 27% and 32% damaged seed, respectively.

The percentage of red sunflower seed weevil damage in 2005 showed high levels of weevil infestation with a range of 2 to 59% damaged seed per head among the germplasm tested (Table 1). Those showing reduced damage levels included the accessions PI 431545 (13.5%) and PI 431542 (2.0%) and the damage sustained by these accessions was statistically lower than 18 of the 21 lines evaluated in 2005. PI 650375 which was only slightly higher at 18% damaged seed per head was significantly lower than fifteen of the tested lines and had been evaluated in both 2003 and 2004 showing only 13% damage each year. PI 431542 had the least damage (2%) of all germplasm evaluated in 2005 as well as in 2004 when it averaged 6% damaged seed per head. Hybrid 894 showed a mean of 43% damaged seed per head which was higher than the 2004 trial of 24% damaged seed per head.

The levels of damage in the 2006 trial were similar to 2005 and showed that high densities of red sunflower seed weevil infestation occurred, with a range of 7 to 52% damaged seed per head among the germplasm tested (Table 1). Five lines showed damage levels of 12% or less (PI 162453, PI 175728, PI 193775, PI 431545, PI 650375,) and of these lines, three were new additions to the 2006 trial. PI 650375, with only 7% damaged seed, was the line with the least damage in the trial and was significantly lower than nine of the lines evaluated in 2006. This line has been consistently among the germplasm with lower damage levels throughout the trials. Although PI 431542 showed greater seed damage than it had in 2005, averaging 14%, it was still below the trial mean of 24% and significantly lower than eight of the lines tested this year. PI 431545 showed slightly less injury, averaging about 10% damaged seed per head, than it had in 2005.

In 2007, the percentage of *S. fulvus* feeding damage among the 22 lines tested was lower than observed in 2006 and ranged from 2.5% in accession PI 181994 to 37.1% in accession PI 650558 (Table 1). The interspecific cross HIR 828-3, was previously selected as a susceptible check, and showed high damage with a mean of 32% damaged seed per head in 2007. Two PIs, 431545 and 431542, which had consistently been among the germplasm with reduced damage from *S. fulvus* in previous trials were again low with only 4.4% and 2.9% damaged seed per head, respectively and were significantly lower than thirteen of the lines evaluated in 2007. PI 650375, another accession from earlier trials, also was among the most resistant germplasm in the trials with only a mean of 7% damaged seed per head. A total of five of the ten lines sustaining less than 11% damaged seed per head were new in the 2007 trial.

Injury levels for the 2008 trial were similar to 2007 with a range of 1.6% to 31.9% damaged seed per head in PI 431542 and hybrid 894, respectively (Table 1). There were nine lines among the 25 evaluated sustaining less than 9% damaged seed per head and of these, seven had also shown less than 9% damaged seed in 2007. These

Table 1. Percentage of seeds damaged by *S. fulvus* per head in selected sunflower accessions evaluated at Highmore, SD, 2004 to 2008.

Accession	*S. fulvus* % damaged seeds per head (mean ± SE)				
	2004	2005	2006	2007	2008
PI 162453	—	—	11.1 ± 3.3g	8.8 ± 2.0fghij	5.3 ± 1.6jkl
PI 170385	—	—	—	26.1 ± 3.7cd	—
PI 170391	—	—	14.3 ± 2.1efg	13.5 ± 1.3ef	23.3 ± 2.6abcde
PI 170401	—	—	16.0 ± 4.4efg	26.7 ± 4.4bcd	—
PI 170405	—	—	24.7 ± 3.5cde	—	—
PI 170407	—	—	—	—	26.1 ± 4.1abcd
PI 170408	—	—	—	—	25.0 ± 4.1abcd
PI 170414	—	—	—	34.5 ± 3.3ab	
PI 175728	—	—	11.3 ± 2.4fg	22.1 ± 3.3de	31.5 ± 4.2ab
PI 175730	—	—	—	—	18.9 ± 2.5cdefg
PI 181994	—	—	—	2.5 ± 1.4l	4.4 ± 1.5jkl
PI 193775	—	—	10.9 ± 2.2fg	14.5 ± 2.7ef	8.5 ± 2.2hijk
PI 195573	—	—	—	4.5 ± 0.9ijkl	11.4 ± 5.2hij
PI 219649	—	—	—	12.4 ± 3.2fgh	3.3 ± 1.0jkl
PI 250085	—	—	—	10.2 ± 1.7fghi	12.6 ± 2.9ghi
PI 250855	—	—	—	8.6 ± 1.7fghij	7.7 ± 2.6ijk
PI 251465	—	—	—	—	20.8 ± 2.1bcdef
PI 251902	—	—	16.5 ± 5.3efg	—	—
PI 253776	33.5 ± 3.0b	—	—	—	—
PI 265503	—	—	30.4 ± 5.3bcd	—	—
PI 267665	30.8 ± 1.7bc	—	—	—	—
PI 291403	34.9 ± 2.5b	—	—	—	—
PI 372259	—	—	36.9 ± 5.2bc	—	—
PI 386230	19.9 ± 2.1def	—	—	—	—
PI 431506	18.8 ± 1.7defg	38.5 ± 4.1cde	38.2 ± 6.5bc	—	26.7 ± 4.0abc
PI 431513	13.8 ± 4.1fg	—	—	—	—
PI 431514	—	37.2 ± 3.5cde	—	—	—
PI 431516	—	36.3 ± 3.7cdef	—	—	—
PI 431518	—	45.4 ± 3.4bc	—	—	—
PI 431520	—	29.5 ± 3.9efgh	—	—	—
PI 431524	—	39.7 ± 4.4cde	—	—	—
PI 431525	—	—	—	—	13.7 ± 2.6fgh
PI 431528	—	42.9 ± 4.2bcd	—	—	—
PI 431529	—	32.5 ± 6.5defg	—	—	—
PI 431537	—	—	—	—	19.9 ± 3.0cdefg
PI 431542	6.0 ± 1.6h	2.0 ± 0.8j	14.0 ± 5.3fg	2.9 ± 0.7kl	1.6 ± 0.5l
PI 431545	—	13.5 ± 5.5i	10.4 ± 3.5g	4.4 ± 0.9jkl	4.3 ± 0.9jkl
PI 431549	—	41.9 ± 2.7bcd	—	—	—
PI 431563	—	35.8 ± 2.4cdef	—	—	—
PI 431568	—	25.3 ± 3.5gh	—	—	—
PI 431569	—	36.0 ± 4.1cdef	—	—	—
PI 432516	—	—	—	6.2 ± 1.6hijk	3.5 ± 1.4kl
PI 494859	31.4 ± 2.6bc	—	—	—	—
PI 494861	—	—	—	12.5 ± 1.3ef	18.9 ± 5.4defg
PI 497939	12.6 ± 1.8g	53.7 ± 3.9ab	—	—	—
PI 505651	21.1 ± 2.7de	—	—	—	—
PI 650375	12.5 ± 1.6g	18.0 ± 1.9hi	7.3 ± 0.7g	6.8 ± 3.4ghijk	7.1 ± 0.9hij
PI 650497	23.6 ± 1.9cd	25.3 ± 2.1fgh	—	—	—
PI 650558	16.7 ± 5.3efg	35.4 ± 4.1cdef	52.1 ± 5.4a	37.1 ± 3.9a	—
HIR 828-3	49.0 ± 3.7a	58.9 ± 2.9a	20.5 ± 3.3def	32.0 ± 3.8abc	21.6 ± 3.8bcdef
PAR 1673-1	—	—	14.7 ± 3.9efg	11.9 ± 1.2fg	14.3 ± 2.5efgh

Table 1. Continued.

Accession	*S. fulvus* % damaged seeds per head (mean ± SE)				
	2004	2005	2006	2007	2008
PRA PRA 1142	—	—	41.7 ± 4.0ab	—	—
STR 1622-1	27.2 ± 2.7bcd	—	—	—	—
STR 1622-2	32.4 ± 4.5bc	34.0 ± 2.7cdefg	29.3 ± 5.9bcd	10.4 ± 2.7fghi	26.5 ± 3.6abc
Hybrid 894	23.9 ± 1.2cd	43.3 ± 1.5bc	33.6 ± 2.5bc	20.7 ± 1.6de	31.9 ± 3.4a
Mean	26.0	37.6	23.8	15.6	15.6

Means followed by the same letter within each year are not significantly different ($P < 0.05$; LSD); Percentages were transformed to square root of the arcsine before significance analysis but untransformed means are presented; 2–67 heads examined per accession each year.

included, PI 162453, PI 181994, PI 250855, PI 431542, PI 431545, PI 432516, and PI 650375. These accessions sustained significantly lower seed damage than 12 other lines in 2008. The accession PI 431542, which was the lowest in the trial, sustained less than 7% damaged seed per head in four of the five years of evaluation. PI 181994 in the second year of testing only showed 4% damaged seed in 2008 and in 2007 had sustained only 3% damaged seed per head. Another accession which had first been evaluated in 2007 also showed resistance to *S. fulvus* seed damage, with 3.5% in 2008 and only 6.2% damaged seed per head in 2007.

Discussion

Evaluation of different sunflower germplasm over a six-year period revealed germplasm with resistance to larval feeding by the red sunflower seed weevil. The accession PI 162453 averaged only 8% damage in three years of testing and PI 431545 averaged 8% in four years of testing. PI 162453 was originally obtained from Urguay in 1948 and PI 431545 from the former Serbia and Montenegro in 1979. The accessions PI 431542 and PI 650375, which were tested for five years, averaged 5% and 10%, respectively throughout the trials, while PI 431542 was below 6% in all but one year of testing. PI 431542 was also obtained in 1979 in the former Serbia and Montenegro, while PI 650375 was a collection from Germany in 1985. Additional accessions that appeared promising in two consecutive years of trials included PI 195573 (Ethopia, 1951) at 5 and 11%, PI 219649 (Austria, 1954) at 12 and 3%, PI 250085 (Egypt, 1958) at 9 and 8%, and PI 432516 (New Mexico, 1978) at 6 and 4% in 2007 and 2008, respectively.

There were a total of five interspecific crosses evaluated from one to six years. HIR 828-3 (*H. hirsutus* Rafinesque) which was used as a susceptible check averaged much higher percentage of damaged seed than the trial mean in all but one year. STR 1622-2 (*H. strumosus* L.), which was tested for five years, sustained greater than 26% damaged seed per head in four of those trials. The interspecific cross, PAR 1673-1 (*H. paradoxus* Heiser), showed the lowest damaged seed per head among lines of this type, but still averaged over 14% damaged seed per head in three years of trials.

Hybrid 894 was included in these trials as a standard check and is a public domain hybrid that previously has been produced by a number of commercial sources. In the current research, this hybrid consistently had high seed damage from *S. fulvus* feeding among the different germplasm evaluated. In all but one year it sustained damage higher than the trial mean. However, in resistance trials with the banded sunflower moth, *Cochylis hospes* Walsingham, another important seed-feeding pest of sunflower, it was among the most resistant of the lines studied (Charlet *et al.*, 2009).

The type of resistance responsible for reduced *S. fulvus* feeding injury in germplasm identified in our research is not currently known. Earlier studies by Brewer and Charlet (1995) and Gao and Brewer (1998) detected both antixenosis and antibiosis in accessions that they evaluated. The importance of incorporating more than one resistance mechanism to reduce damage by the red sunflower seed weevil is important to overcome a number of factors involved in the attraction of *S. fulvus* to sunflower, such as selection of the plant for feeding by the adults, oviposition by the female into the developing achenes, and subsequent larval feeding on the kernel. As shown by Roseland *et al.* (1990, 1992) optimal host-finding was dependent on a combination of monoterpenoids and other volatiles, but that a male-produced pheromone also had a role in host discrimination and attraction of female weevils to sunflowers. Gao and Brewer (1998) also noted that pollen and seed color were associated with differences in resistance in some of the lines tested. Additional research will be required to investigate the lines showing resistance to injury by the red sunflower seed weevil to determine which resistance mechanisms are important.

The potential for developing resistant genotypes to decrease seed feeding injury caused by the red sunflower seed weevil and aid sunflower growers in preventing yield loss is promising. The ability to utilize host plant resistance for controlling this insect pest would add another strategy in an integrated pest management approach. Although shown to be valuable, chemical control is expensive and treatment decisions require time-consuming field scouting and sampling, as well as accurate timing for effective control (Oseto and Burr, 1990). In addition, plant resistance can be effectively combined with other integrated pest management strategies, such as delayed planting (Oseto *et al.*, 1987; Charlet, 2002) and trap cropping (Brewer and Schmidt, 1995), which have been shown to reduce densities of *S. fulvus* and reduce crop losses. Research is in progress to introgress resistance genes from the identified lines into cultivated sunflower through conventional breeding facilitated by the use of marker-assisted selection.

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Literature Cited

Aslam, M., and G. E. Wilde. 1991. Potential insect pests of sunflower in Kansas. Journal of the Kansas Entomological Society 64:109–112.

Brewer, G. J. 1991. Oviposition and larval bionomics of two weevils (Coleoptera: Curculionidae) on sunflower. Annals of the Entomological Society of America 84:67–71.

Brewer, G. J., and L. D. Charlet. 1995. Mechanisms of resistance to the red sunflower seed weevil in sunflower accessions. Crop Protection 14:501–503.

Brewer, G. J., and G. Schmidt. 1995. Trap cropping to manage the red sunflower seed weevil in oilseed sunflower. American Journal of Alternative Agriculture 10:184–187.

Carmer, S. G., and W. M. Walker. 1985. Pairwise multiple comparisons of treatment means in agronomic research. Journal of Agronomic Education 14:19–26.

Charlet, L. D. 2002. Parasitization of the red sunflower seed weevil (Coleoptera: Curculionidae) by its larval parasitoid, *Triaspis aequoris* (Hymenoptera: Braconidae) in cultivated sunflower. Environmental Entomology. 31:844–851.

Charlet, L. D., and G. J. Seiler. 1994. Sunflower seed weevils (Coleoptera: Curculionidae) and their parasitoids from native sunflowers (*Helianthus* spp.) in the Northern Great Plains. Annals of the Entomological Society of America 87:831–835.

Charlet, L. D., and P. A. Glogoza. 2004. Insect problems in the sunflower production regions based on the 2003 sunflower crop survey and comparisons with the 2002 survey. Proc. 26th Sunflower Research Workshop, Natl. Sunflower Assoc., Fargo, ND, 14–15 January 2004. URL: <http://www.sunflowernsa.com/research/research-workshop/documents/143.pdf > [Last accessed 1/1/2010].

Charlet, L. D., G. J. Brewer, and B. Franzmann. 1997. Insect pests. *In* Schneiter, A. A. (ed.). Sunflower technology and production. Agronomy Series 35, pp. 183–261. American Society of Agronomy. Madison, WI. 834 pp.

Charlet, L. D., G. J. Seiler, J. F. Miller, B. S. Hulke, and J. J. Knodel. 2009. Resistance among cultivated sunflower germplasm to the banded sunflower moth (Lepidoptera: Tortricidae) in the northern Great Plains. Helia 32(51):1–10.

Gao, H., and G. J. Brewer. 1998. Sunflower resistance to the red sunflower seed weevil (Coleoptera: Curculionidae). Journal of Economic Entomology 91:779–783.

Gednalske, J. V., and D. D. Walgenbach. 1982. Planting date and tillage as weevil control aids. The Sunflower 8(2):42–43.

Gednalske, J. V., and D. D. Walgenbach. 1984. Influence of insecticide application timing on damage by *Smicronyx fulvus* and *S. sordidus* (Coleoptera: Curculionidae). Journal of Economic Entomology 77:1545–1548.

Oseto, C. Y., and G. A. Braness. 1979. Bionomics of *Smicronyx fulvus* (Coleoptera: Curculionidae) on cultivated sunflower, *Helianthus annuus*. Annals of the Entomological Society of America 72:524–528.

Oseto, C. Y., and G. A. Braness. 1980. Chemical control and bioeconomics of *Smicronyx fulvus* on cultivated sunflower in North Dakota. Journal of Economic Entomology 73:218–220.

Oseto, C. Y., and W. F. Burr. 1990. Timing insecticide applications for control of the red sunflower seed weevil (Coleoptera: Curculionidae) on cultivated sunflower. Journal of Agricultural Entomology 7:337–341.

Oseto, C. Y., J. D. Busacca, and L. D. Charlet. 1987. Relationship of sunflower planting dates to damage by *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae) in North Dakota. Journal of Economic Entomolgy 80:190–192.

Peng, C., and G. J. Brewer. 1995. Economic injury levels for the red sunflower seed weevil (Coleoptera: Curculionidae) infesting oilseed sunflower. Canadian Entomologist 127:561–568.

Pinkham, J. D., and C. Y. Oseto. 1987. Natural enemies and their mortality rates on *Smicronyx fulvus* LeConte (Coleoptera: Curculionidae) larvae. Environmental Entomology 16:1302–1304.

Rana, R. L., and L. D. Charlet. 1997. Feeding behavior and egg maturation of the red and gray sunflower seed weevils (Coleoptera: Curculionidae) on cultivated sunflower. Annals of the Entomological Society of America. 90:693–699.

Roseland, C. R., M. B. Bates, and C. Y. Oseto. 1990. Role of a male-produced pheromone of the red sunflower seed weevil (Coleoptera: Curculionidae) in host finding. Environmental Entomology 19:1675–1680.

Roseland, C. R., M. B. Bates, R. B. Carlson, and C. Y. Oseto. 1992. Discrimination of sunflower volatiles by the red sunflower seed weevil. Entomol. Exp. Appl. 62:99–106.

SAS Institute. 2008. SAS system for windows. Release 9.01. SAS Institute, Cary, NC. 1,906 pp.